Virginia Stormwater Management:

Nutrient Design System

CONTENTS

Center for Watershed Protection
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Nutrient Design System -- Introduction

The following sections outline a system for selecting Best Management Practices (BMPs) at development sites to meet Virginia nutrient reduction standards. The system is divided into the following sections:

SECTION 1 explains the overall process and provides a BMP Lookup Table based on a site's post-development impervious cover. The BMP Lookup Table can be used to quickly ascertain candidate BMPs for different land use categories.

SECTION 2 outlines a series of Low-Impact Development (LID) Credits that can be used to reduce reliance on structural BMPs. The Section provides guidance on calculating the benefits of using LID Credits, and is accompanied by an LID Credit Spreadsheet.

SECTION 3 provides documentation for a Performance Calculation Method. This is an alternative to the BMP Lookup Table, and can be used for special situations where site-based load calculations are required.

SECTION 4 is a sample BMP specification and checklist that will be used in conjunction with the other procedures presented in the Nutrient Design System. The sample specification is for two levels of Bioretention design. It is intended that this information will ultimately be included in an updated Stormwater Management Handbook.

The following Appendices provide more detailed information on selected subjects.

Appendix A: Analysis of Virginia Event Mean Concentrations (EMCs) and Land Use Loading Rates from the National Stormwater Quality Database (2007)

Appendix B: Stormwater Quality Computation Approaches & Profile Sheets

Appendix C: Updated BMP Removal Efficiencies from the National Pollutant Removal Database (2007) & Acceptable BMP Table for Virginia

Section 1

Overall Method & BMP Lookup Table

The following 8 steps outline the process for BMP selection and compliance at a development site. The process is divided into: (1) preliminary assessment of the site and BMP options, and (2) using LID Credits and the BMP Lookup Table. **Figure 1.1** provides a flowchart for the overall process.

PRELIMINARY ASSESSMENT

STEP 1: DETERMINE DRAINAGE AREAS & POST-DEVELOPMENT IMPERVIOUS COVER

Divide the site into drainage areas and calculate the post-development impervious cover for each drainage area from the preliminary or concept plan.

STEP 2: CLASSIFY THE SITE

Determine whether the site is classified as **New Development** or **Redevelopment** (according to definitions provided in the Regulations). For New Development sites, proceed with Steps 3 through 8. Redevelopment sites should follow the appropriate process below:[1]

- If the impervious cover AFTER redevelopment for any drainage area is less than or equal to 40%, then use the actual post-development impervious cover in Steps 3 through 8 (just like New Development).
- If the impervious cover AFTER redevelopment for any drainage area is greater than 40%, then the drainage area must achieve a 28% reduction in Total Nitrogen load from the condition PRIOR to redevelopment (pre-existing condition). The BMP selection process for these cases can use the BMP Lookup Table approach (Steps 3 through 8 below) or the Performance Calculation Method (**SECTION 3**).

STEP 3: ASSESS UNIQUE CIRCUMSTANCES

Assess unique or unusual circumstances at the site. These may include:

- Part of Regional or Watershed Plan: If the site is covered by a local or regional watershed plan that prescribes certain BMPs or management measures, then the proper authority should be consulted. In some cases, the local government may have an approved **pro-rata share** or **fee-in-lieu** program that allows for some off-site compliance.

[1] The approach for Redevelopment is still under consideration, so the guidance provided in Step 2 should be considered provisional. Various approaches for redevelopment have been considered, including: (1) having a technology table (BMP Lookup) for redevelopment, (2) using the pre-development impervious cover in the BMP Lookup Table in some cases, and (3) using a computation to verify 28% reduction in Total Nitrogen loads from the pre-existing condition.

Also, CWP presented two different scenarios for Redevelopment: (1) cases where the project is within a targeted development zone identified in the local comprehensive and land use plans, and (2) cases where the project is outside of such a zone. The policy issue is whether to provide incentives for redevelopment within targeted zones by having less stringent on-site stormwater requirements, and how much of an incentive to provide, given the need to strive for load reductions from the pre-existing condition. This is an important consideration, since development that does not take place within targeted zones can likely contribute to more widespread impervious cover and pollutant loadings across the broader watershed.

- Part of a TMDL Implementation Plan: If the site is covered by an implemented TMDL plan that requires site-based pollutant load calculations, the designer should consult with the proper local or regional authority. In some cases, additional calculations may have to be performed. In these cases, the Performance Calculation Method may be applied (see **SECTION 3**).

STEP 4: DETERMINE IMPERVIOUS COVER CATEGORY

Determine whether each drainage area is in the LOW IMPERVIOUS (less than or equal to 40% post-development impervious cover) or HIGH IMPERVIOUS (greater than 40% post-development impervious cover) category.

STEP 5: EARLY ASSESSMENT OF LID CREDITS

Review the LID Credits in **SECTION 2**. Many sites can utilize some of these credits to reduce the size, number, and cost of structural BMPs. Make a preliminary assessment of which credits are most applicable to the site and to each drainage area.

BMP LOOKUP TABLE & LID CREDITS

STEP 6: APPLY LID CREDITS

If LID Credits will be used, consult **SECTION 2** and follow the LID Credit and BMP Selection procedures. The LID Credit Spreadsheet can be used to quickly determine the benefit of applying various LID scenarios in terms of reducing overall structural BMP use at the site.

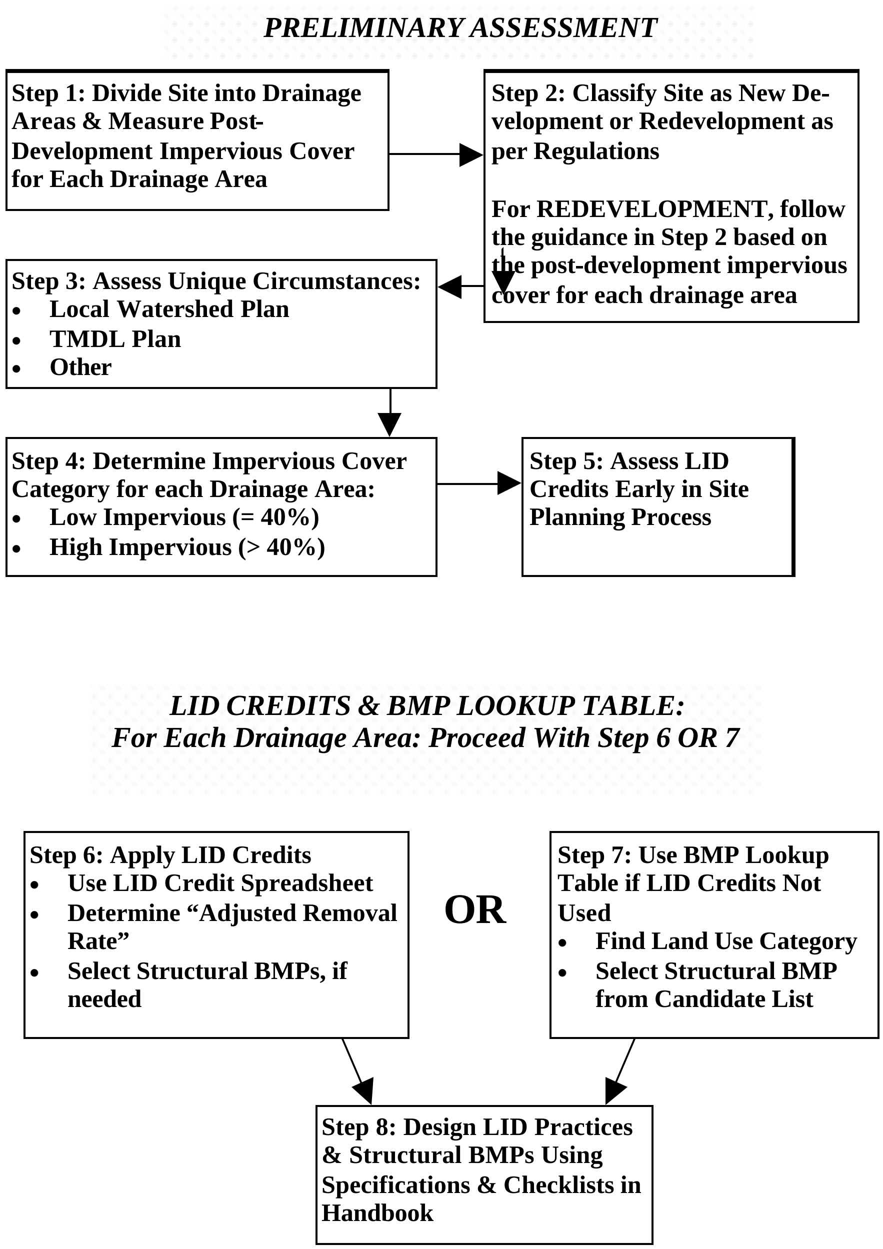
STEP 7: USE BMP LOOKUP TABLE IF LID CREDITS NOT USED

If LID Credits will NOT be used for some or all of the drainage areas, use the BMP Lookup Table (**Table 1.1**) to guide BMP selection. In the table, find the appropriate LOW IMPERVIOUS or HIGH IMPERVIOUS category for each drainage area based on the post-development impervious cover. This table will prescribe the drainage area's post-development load for phosphorus and nitrogen, BMP removal rates, and candidate BMPs that can be used for compliance. The designer should use a combination of LID Credits and BMPs that is best suited to site conditions.

STEP 8: DESIGN LID PRACTICES & STRUCTURAL BMPs

After the LID Credits and BMPs are selected, the site designer should design the LID measures and BMPs based on specifications (***in the Handbook***). For each type of BMP, ALL sizing and design features listed in the BMP checklist must be incorporated into the design. See **SECTION 4** for sample BMP specifications and checklist (Bioretention).

Figure 1.1: Nutrient Design System Flowchart



Methodology & Assumptions for BMP Lookup Table

1. The table is a simplified compliance method which allows the focus to be on BMP design rather than load computations. However, the table also allows for quantifying compliance with Tributary Strategy goals for urban land. Performance goals for urban land were identified by the Department of Conservation & Recreation (DCR) based on load limits needed to meet Tributary Strategy goals.
2. The table provides post-development loads and BMP removal rates for both Total Phosphorus (TP) and Total Nitrogen (TN). The table divides LOW IMPERVIOUS sites (less than or equal to 40% impervious) from HIGH IMPERVIOUS sites (greater than 40% impervious). The reason for this is that stormwater quality is generally different for the two types of sites. Data from the National Stormwater Quality Database (NSQD), sorted for Virginia, indicate that Low Impervious sites (generally residential land uses) produce higher concentrations of both TP and TN than High Impervious sites (generally non-residential land uses). The reason for this is that Low Impervious sites have more turf and pervious areas, some of which may be fertilized and/or subject to soil loss. This is particularly important for TP. The difference between TP and TN concentrations between the two types of sites is generally offset by the increased rates of runoff (and thus increased overall loads) from High Impervious sites. See **Appendix A** for a detailed analysis from the NSQD of Virginia Event Mean Concentrations (EMCs) in stormwater runoff.
3. Based on a statistical analysis of the NSQD for Virginia, the flow-weighted mean concentrations were selected as follows:

Flow-Weighted Mean Concentrations (C) – milligrams/liter

	Total Phosphorus	***Total Nitrogen***
Low Impervious Sites (< 40%)	*0.28 mg/L*	*2.67 mg/L*
High Impervious Sites (> 40%)	*0.23 mg/L*	*1.12 mg/L*

4. Virginia's method is based on each site achieving certain performance standards for TP and TN. These performance standards were selected based on load reductions for Urban Land needed to achieve Tributary Strategy goals. Again, the performance standards are variable for Low Impervious and High Impervious sites. For Low Impervious sites, TP is the critical pollutant, since phosphorus is more highly correlated with the variety of land covers characteristic of these sites (including yards and other areas of managed turf). For High Impervious areas, TN is selected as the critical pollutant, since runoff from impervious areas usually has fewer particulates (which more readily bind with phosphorus) and is also more subject to nitrogen sources associated with atmospheric deposition.
5. Based on the rational in #4, the performance standards are as follows:

Performance Standards for Phosphorus & Nitrogen – pounds/acre/year

	Total Phosphorus	***Total Nitrogen***
Low Impervious Sites (< 40%)	*0.28 pounds/acre/year*	*3.00 pounds/acre/year*
High Impervious Sites (> 40%)	*0.45 pounds/acre/year*	*2.68 pounds/acre/year*

6. Post-Development Loads are based on the Simple Method computation, as follows:

   Simple Method Calculation:

   $L = P \times P_j \times R_v \times C \times A \times 2.72/12$

   Where:

   L = total post-development pollutant load (pounds/ year)
   P = average annual rainfall depth (inches) = 43 inches for Virginia
   P_j *= fraction of rainfall events that produce runoff = 0.9*
   R_v *= runoff coefficient = [0.05 + (0.009 x I)]*
   where: I = percent impervious cover, expressed as whole number
   C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) – see #3 above
   A = area of the development site (acres)
   2.72 and 12 are unit conversion factors

   See **SECTION 3** (Performance Computation Method) for a complete documentation of load computations and calculation of BMP Removal Rates required for a site.

7. In the BMP Lookup Table, land use categories were selected based on inflection points in percent impervious vs. removal rate curves. Each category reflects a relatively narrow range of BMP removal rates. Removal rates listed for each category are those associated with the high end of impervious cover for the category (e.g., used 30% impervious for the category 26-30%).
8. The candidate BMP removal rates are based on 2007 updates to the National Pollutant Removal Database along with professional judgment. The removal rates for the various BMPs are shown in the table below. Candidate BMPs in each land use category are those that are within a reasonable range of the required pollutant removal rate for the critical pollutant (TP for Low Impervious sites and TN for High Impervious sites).

   Studies of BMP pollutant removal efficiency indicate a wide variability of BMP performance based on a variety of factors, including: design features, influent concentration, particle size distribution of runoff, flow rates, soils, and other site factors. Due to the wide range of published removal efficiencies, the BMP categories were divided into two group to isolate the design features that can boost removal efficiency. For instance, bioretention designs include Bioretention #1 and Bioretention #2. The first category can be seen as the "standard" design, while the second category includes sizing and design features that have been shown in research to improve performance beyond the median removal efficiency. **SECTION 4** contains sample specifications and checklists for Bioretention #1 and #2. Ultimately, the BMP specifications, checklists, and standard designs will be included in the updated ***Handbook and/or BMP Clearinghouse website.***

In some cases, professional judgment was used to match appropriate BMPs to certain levels of impervious cover, especially at the higher ranges of impervious cover. This was done so that compliance can be achieved on-site with a "maximum extent practical" approach. Another consideration is that certain BMPs (e.g., bioretention) have been shown to achieve significant volume reductions that are not accounted for in a strict concentration in vs. concentration out study. Volume reductions will result in overall load reductions which are not accounted for in the percent removal approach. As such, the Lookup Table allows bioretention at higher levels of impervious cover, even if the listed removal efficiency for the land use category is not met.

See **Appendix C** for a more detailed analysis of pollutant removal rates for various types of BMPs.

BMP Removal Rates Used in the BMP Lookup Table

BMP Type	TP Removal Efficiency	TN Removal Efficiency
Wet Pond 1	50%	30%
Wet Pond 2	75%	40%
Bioretention 1	45%	45%
Bioretention 2	55%	55%
Infiltration 1	65%	40%
Infiltration 2	95%	65%
Constructed Wetland 1	45%	25%
Constructed Wetland 2	75%	55%
WQ Swale 1	25%	45%
WQ Swale 2	45%	55%
Filtering Practice	65%	50%

TABLE 1.1: BMP LOOKUP TABLE

Land Use Category & Post-Development Impervious Cover Range	Post-Development Loads for Total Phosphorus (TP) & Total Nitrogen (TN)	Pollutant Removal Rate (%RR) Required for TP & TN	Candidate BMPs
LOW IMPERVIOUS (= 40%)			
Low Impervious # 1 I = 0 – 10%	TP = 0.34 lbs/acre/yr; TN = 3.28 lbs/acre/yr	TP = 20% TN = 10%	1. Good Rural Site Design Principles (no structural BMPs required)
Low Impervious # 2 I = 11 – 15%	TP = 0.45 lbs/acre/yr; TN = 4.33 lbs/acre/yr	TP = 40% TN = 30%	1. Wet Pond #1 2. Bioretention #1 3. Infiltration #1 4. Wetland #1 5. WQ Swale #2
Low Impervious # 3 I = 16 – 20%	TP = 0.56 lbs/acre/yr; TN = 5.39 lbs/acre/yr	TP = 50% TN = 45%	1. Wet Pond #1 2. Bioretention #2 3. Infiltration #1 4. Wetland #2
Low Impervious # 4 I = 21 – 25%	TP = 0.68 lbs/acre/yr; TN = 6.44 lbs/acre/yr	TP = 60% TN = 55%	1. Wet Pond #2 2. Bioretention #2 3. Infiltration #1 4. Wetland #2 5. Filtering Practice
Low Impervious # 5 I = 26 – 30%	TP = 0.79 lbs/acre/yr; TN = 7.49 lbs/acre/yr	TP = 65% TN = 60%	1. Wet Pond #2 2. Bioretention #2 3. Infiltration #1 4. Wetland #2 5. Filtering Practice
Low Impervious # 6 I = 31 – 40%	TP = 1.01 lbs/acre/yr; TN = 9.60 lbs/acre/yr	TP = 70% TN = 70%	1. Wet Pond #2 2. Infiltration #2 3. Wetland #2 4. Filtering Practice

TABLE 1.1: BMP LOOKUP TABLE (Continued)

Land Use Category & Post-Development Impervious Cover Range	Post-Development Loads for Total Phosphorus (TP) & Total Nitrogen (TN)	Pollutant Removal Rate (%RR) Required for TP & TN	Candidate BMPs
HIGH IMPERVIOUS (> 40%)			
High Impervious # 1 I = 41 – 50%	TP = 1.01 lbs/acre/yr; TN = 4.91 lbs/acre/yr	TP = 55% TN = 45%	1. Bioretention #1 2. Infiltration #2 3. Wetland #2 4. WQ Swale #1 5. Filtering Practice
High Impervious # 2 I = 51 – 60%	TP = 1.19 lbs/acre/yr; TN = 5.80 lbs/acre/yr	TP = 60% TN = 55%	1. Bioretention #2 2. Infiltration #2 3. Wetland #2 4. WQ Swale #2 5. Filtering Practice
High Impervious # 3 I = 61 – 75%	TP = 1.46 lbs/acre/yr; TN = 7.12 lbs/acre/yr	TP = 70% TN = 60%	1. Bioretention #2 2. Infiltration #2 3. Wetland #2 4. Filtering Practice (Enhanced – expanded pre-treatment)
High Impervious # 4 I > 75%	TP = 1.74 lbs/acre/yr; TN = 8.45 lbs/acre/yr	TP = 75% TN = 70%	1. Bioretention #2 2. Infiltration #2 3. Filtering Practice (Enhanced – expanded pre-treatment)

Section 2

Low-Impact Development (LID) Credits

METHOD FOR COMPUTING LID CREDITS

LID Credits are based on the ability of various LID practices to reduce the overall VOLUME of runoff from a development site. Reducing the volume of runoff leads to an overall reduction of pollutant loads. This method does not directly account for other pollutant removal advantages of LID practices, such as filtering or infiltration of pollutants. At this point in time, there have not been enough studies to consistently document the pollutant removal functions of various LID practices, especially at the scale of the entire site. However, the volume reduction components of these studies are more consistent and conclusive.

The following five steps outline the process for using LID Credits. The LID Credit Spreadsheet should also be used as part of this procedure.

STEP 1: SITE NATURAL FEATURES INVENTORY

Review the site to identify important natural and drainage features, including streams, riparian areas, wetlands, flood plains, slopes, natural drainage swales/features, forest cover, specimen trees, groundwater recharge or protection areas, pervious soils (hydrologic soil groups A and B), sinkholes and karst features, important habitat features, etc. Strive to maximize protection of these features as protected open space. REVIEW LID CREDITS 1 – 4 & COMPUTE ACREAGES FOR EACH CREDIT (see **Table 2.1**).

STEP 2: SELECT LID FEATURES TO TREAT SITE AREAS

Review the other LID Credits in **Table 2.1** (Credits 5 – 11). Determine impervious and pervious areas of the site that can be treated using the methods outlined in the Table. This is likely an iterative process, and will require reference to the design guidelines and specifications for each credit. Multiple credits can be used at a particular site, but "double-counting" of credits is not allowed. That is, each area (e.g., a single rooftop) can only be counted once.

STEP 3: DETERMINE ADJUSTED IMPERVIOUS AREA & ADJUSTED BMP REMOVAL RATE

Enter all relevant Credit acreages in the appropriate LID Credit Spreadsheet (screenshot of Spreadsheet in **Figure 2.3**). There is one spreadsheet for LOW Impervious Cover sites (Initial impervious cover < 40%) and one for HIGH Impervious Cover sites (Initial impervious cover > 40%). The spreadsheet will compute the "Adjusted Impervious Cover" and "Adjusted BMP Removal Rate" for the site. The Adjusted BMP Removal Rate can be confirmed on the LID Credit Curves – **Figures 2.1 and 2.2**. **Figure 2.1** (Low Impervious sites) is based on the pollutant removal efficiency curve for Total Phosphorus (TP). **Figure 2.2** (High Impervious sites) is based on the pollutant removal efficiency curve for Total Nitrogen (TN). See **SECTION 1** and the BMP Lookup Table for further documentation.

STEP 4: SELECT STRUCTURAL BMPs TO USE IN CONJUNCTION WITH LID CREDITS

On the appropriate BMP Table (see the Spreadsheet & **Figures 2.1 and 2.2**), find the candidate structural BMPs that can meet the Adjusted BMP Removal Rate. These are the BMPs that can be used in conjunction with the LID Credits for site compliance. If the Adjusted Removal Rate is less than 25%, then no additional BMPs are needed, and LID Credits alone can be used at the site.

STEP 5: DESIGN LID FEATURES

Once the LID Credits to be used at a site are confirmed, then the LID features should be designed on the plan in accordance with applicable design specifications in ***the Handbook***.

TABLE 2.1: DESCRIPTION OF LID CREDITS

Credit	Volume Reduction Credit	Application
1. Reforesting Riparian Area	<u>Unit</u> Acres reforested <u>Credit</u> 50%	▪ If Resource Protection Area (RPA) is already required, credit is for reforesting RPA that is currently in grass/turf and/or developed ▪ If RPA is not required, credit is for reforesting minimum of 35' stream buffer along perennial or intermittent streams that is currently in grass/turf and/or developed ▪ Areas receiving credits must be covered by protective easement and maintenance plan ▪ All flow to buffer must be converted to sheet flow – no short-circuiting ▪ Signage provided
2. Expanding & Protecting Riparian Area	<u>Unit</u> Acres of expanded riparian area <u>Credit</u> 50%	▪ If RPA is required, credit is for expanding minimum width to include non-RPA wetlands, adjacent slopes, flood plains, significant forest patches, intermittent streams, and/or other critical habitat features ▪ If RPA is not required, credit is for expanding minimum stream buffer width (beyond 35') to include wetlands, adjacent slopes, significant forest patches, and/or other critical habitat features ▪ Areas receiving credits must be covered by protective easement and maintenance plan ▪ All flow to buffer must be converted to sheet flow – no short-circuiting ▪ Signage provided
3. Open Space Conservation	<u>Unit</u> Acres conserved <u>Credit</u> 75% for A/B Soils 50% for C/D Soils	▪ Credit for non-riparian open space area. Area does not have to receive or treat site runoff ▪ Area covered by protective easement and maintenance plan ▪ Area to be maintained with natural vegetative cover, preferably forest. Maintained turf does not qualify. ▪ Signage provided

Credit	Volume Reduction Credit	Application
4. Open Space Conservation With Hydrologic Function	<u>Unit</u> Acres conserved <u>Credit</u> 100% for A/B Soils 75% for C/D Soils	▪ Credit for non-riparian open space area that is configured to capture site runoff, including natural drainage features (swales) and "designed" open space ▪ Energy dissipation, flow path, and slope guidelines to be followed for any runoff entering area ▪ Area covered by protective easement and maintenance plan ▪ Area to be reforested if currently not in forested condition ▪ Signage provided
5. On-Lot Rain Garden, Dry Well, Infiltration Practice	<u>Unit</u> Acres of rooftop, yard, & driveway treated <u>Credit</u> 100% for A/B Soils 50% for C/D Soils	▪ Credit is for practices that effectively disconnect the rooftop and driveway from other site impervious areas and reduce overall runoff volume ▪ Practice must follow sizing and design guidelines ▪ Practices on C/D soils include underdrain
6. Rainwater Harvesting	<u>Unit</u> Acres of rooftop & other impervious area treated <u>Credit</u> 10% for rain barrel 25% for larger storage, such as cisterns	▪ Credit is for practices that store rainwater from rooftops or other impervious surfaces for reuse ▪ Practices must follow sizing and design guidelines ▪ Maintenance plan provided to ensure that water is used and regularly drained out (e.g., winter)
7. On-Lot Soil Amendments	<u>Unit</u> Acres amended <u>Credit</u> 25% for just soil amended 50% when combined with impervious disconnection (rooftop, driveway, etc.)	▪ Credit for amendment of soils, especially if soils are in hydrologic groups C or D, OR if existing soils are removed or disturbed ▪ To qualify for credit, lot disturbance must be reduced to minimum necessary to construct house, driveway, utilities ▪ Soil amendment and placement must meet specifications

Credit	Volume Reduction Credit	Application
8. Pervious Parking	Unit Acres of pervious parking Acres of impervious area that drain to pervious parking Credit 100% for A/B Soils, infiltration design 50% for C/D Soils, underdrain design 25% for impervious areas that drain to pervious parking	▪ Credit for paver blocks or other pervious surfaces ▪ If infiltration is not feasible, then system may have underdrain in storage layer below surface ▪ Pervious parking must meet design specifications ▪ Preferably, pervious parking area configured to capture runoff from upslope parking and travelways – must meet drainage area/pervious parking area ratio. Also, storage must be increased to account for additional areas.
9. Green Roof	Unit Acres of green roof Credit 75% for Intensive design 50% for Extensive design	▪ Green roof must meet design specifications (LEED?)
10. Grass Channels	Unit Impervious acres draining to grass channels Credit 75% for grass channels in A/B Soils 50% for grass channels in C/D Soils	▪ Credit for non-VDOT grass channels used as part of overall BMP system. ▪ Grass channels can be on property lines, edge of pavement, in open space, etc. ▪ Channels must meet design specifications
11. Other Impervious Disconnection	Unit Impervious acres treated Credit 50% for disconnection to A/B Soils 20% for disconnection to C/D Soils	▪ Credit for impervious disconnection for rooftops, parking lots, and other impervious surfaces when not addressed through another credit ▪ Contributing drainage area, length of flow path, slopes, soils, and other design features must meet specifications ▪ Vegetated filter strips may qualify for this credit (see VSMH, MS 3.14)

LID Credit Computation (See LID Credit Spreadsheet)

The following computation is used in the LID Credit Spreadsheet to compute a site's "Adjusted Impervious Cover" and "Adjusted BMP Removal Rate" based on the use of LID practices. The Adjusted Impervious Cover uses the documented volume reduction associated with LID practices to "discount" impervious cover treated by LID. In other words, impervious cover treated by LID does not produce the same volume of runoff as untreated impervious areas. The Adjusted BMP Removal Rate uses the Adjusted Impervious Cover to recalculate the pollutant removal efficiency to account for the use of LID practices.

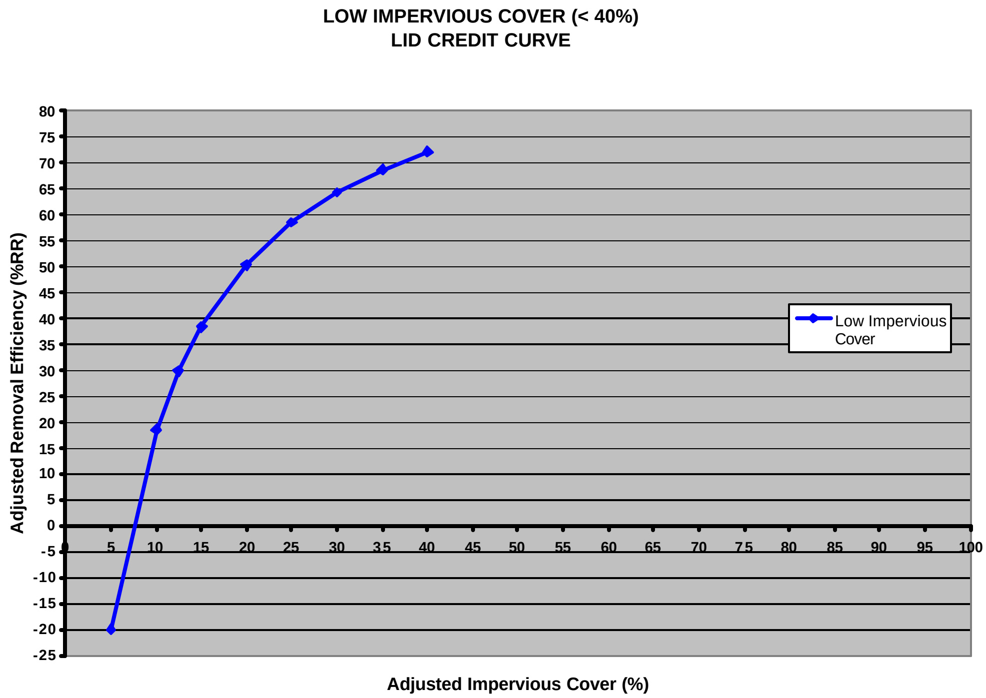
The Spreadsheet calculation is as follows:

Adjusted Impervious Area = Initial Impervious Area – [(CA 1xVRC/100) + (CA 2xVRC/100) + (CA 3xVRC/100) + (CA 4xVRC/100) + (CA 5xVRC/100) + (CA 6xVRC/100) + (CA 7xVRC/100) + (CA 8xVRC/100) + (CA 9xVRC/100) + (CA 10xVRC/100) + (CA 11xVRC/100)]

Where:
CA X = credit area for Credits 1 through 11
VRC = Volume Reduction Credit from ***Table 2.1***

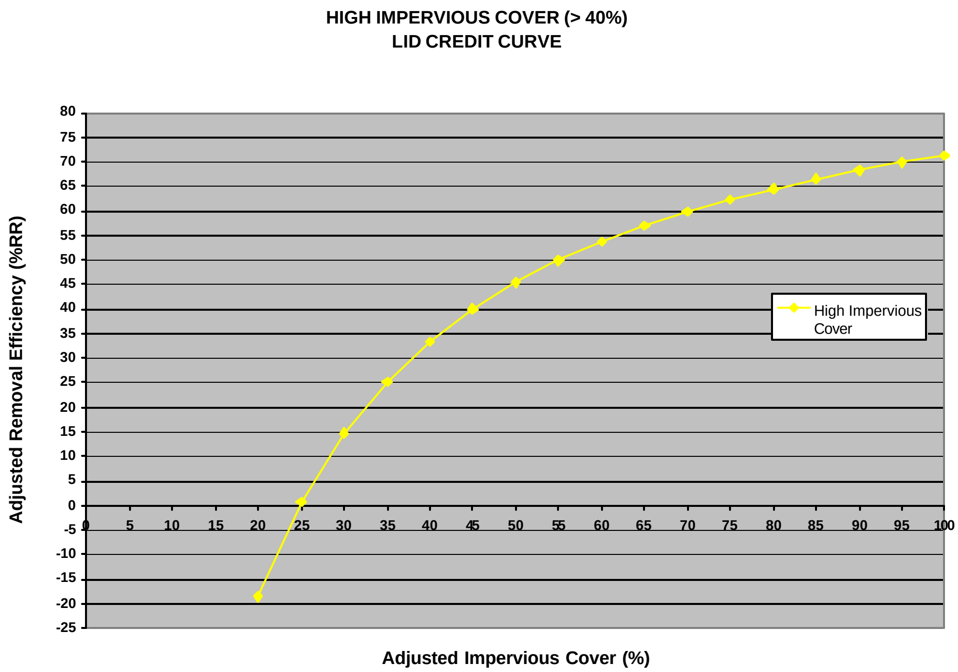
Adjusted BMP Removal Rate = Simple Method Computation for %RR, substituting "Adjusted Impervious Area" for "Initial Impervious Area" ***(See SECTION 3).***

FIGURE 2.1: LID CURVE & REMOVAL RATES FOR LOW IMPERVIOUS COVER SITES (Phosphorus-Based)



BMP Type	Removal Efficiency for LOW Impervious Cover Site (< 40%)
Wet Pond 1	50%
Wet Pond 2	75%
Bioretention 1	45%
Bioretention 2	55%
Infiltration 1	65%
Infiltration 2	95%
Constructed Wetland 1	45%
Constructed Wetland 2	75%
WQ Swale 1	25%
WQ Swale 2	45%
Filtering Practice	65%

FIGURE 2.2: LID CURVE & REMOVAL RATES FOR HIGH IMPERVIOUS COVER SITES (Nitrogen-Based)



BMP Type	Removal Efficiency for HIGH Impervious Cover Site (> 40%)
Wet Pond 1	30%
Wet Pond 2	40%
Bioretention 1	45%
Bioretention 2	55%
Infiltration 1	40%
Infiltration 2	65%
Constructed Wetland 1	25%
Constructed Wetland 2	55%
WQ Swale 1	45%
WQ Swale 2	55%
Filtering Practice	50%

Figure 2.3. Screenshot of LID Credit Spreadsheet

LID Credits -- LOW IMPERVIOUS COVER (< 40%)				
cells in blue are data entry cells				
cells in yellow are calculated results				
Project Name:				
Site Area (acres)	100			
Impervious (%)	40			
Impervious Area (acres)	40			
STEP 1. Credits				
Credit	**Volume Reduction Credit (%)**	**Unit**	**Credit Area (ac)**	**I Reduction (ac)**
1. Reforesting Riparian Area	50	acres reforested	5	2.5
2. Expanding/Protecting Riparian Area	50	acres expanded and/or protected	5	2.5
3. Open Space Conservation				
3.a. A/B Soils	75	acres conserved	0	0
3.b. C/D Soils	50	acres conserved	5	2.5
4. Open Space Conservation w/ Hydrologic Function				
4.a. A/B Soils	100	acres conserved	0	0
4.b. C/D Soils	75	acres conserved	5	3.75
5. On-Lot Rain Garden, Dry Well, Infiltration Practice				
5.a. A/B Soils	100	acres of rooftop treated	0	0
5.b. C/D Soils	50	acres of rooftop treated	5	2.5
6. Rainwater Harvesting				
6.a. Rain Barrels (small storage)	10	acres of rooftop treated	0.5	0.05
6.b. Cisterns (large storage)	25	acres of rooftop treated	0	0
7. On-Lot Soil Amendments				
7.a. Just soil amendment	25	acres amended	3	0.75
7.b. With disconnection	50	acres amended	3	1.5
8. Pervious Parking				
8.a. A/B Soils, infiltration design	100	acres of pervious parking	0	0
8.b. C/D Soils, underdrain design	50	acres of pervious parking	0	0
8.c. Other parking draining to pervious parking	25	acres draining to pervious parking	0	0
9. Green Roof				
9.a. Extensive	50	acres of green roof	0	0
9.b. Intensive	75	acres of green roof	0	0
10. Grass Channels				
10.a. A/B Soils	75	impervious acres draining to grass channel	0	0
10.b. C/D Soils	50	impervious acres draining to grass channel	20	10
11. Other Impervious Disconnection				
11.a. A/B Soils	50	impervious acres treated	0	0
11.b. C/D Soils	25	impervious acres treated	0	0
		TOTAL CREDIT AREA		26.05
		ADJUSTED IMPERVIOUS AREA		13.95
		ADJUSTED IMPERVIOUS %		**14**

STEP 2. BMP Efficiency Requirement		
Parameter (post-development)		
P	Precipitation (in/yr)	43
P_j	Fraction of Runoff Producing Events	0.9
I	Adjusted Imperviousness Cover (%)	14
R_v	Runoff Coefficient	0.18
C	Mean Concentration of Pollutant (mg/L)	0.28
A	Area (acres)	1
	Post-Development Load (lb/yr):	0.43
	Required Removal (0.28 P standard)	0.15
	Adjusted BMP Efficiency Requirement	**35%**

Section 3

Performance Calculation Method

PERFORMANCE CALCULATION METHOD (PCM)
Apply to Each Drainage Area on the Site

IMPORTANT: The first step should always be to determine which LID Credits are applicable to the site. See the LID Credits in SECTION 2.

PCM STEP 1: Calculate Post-Development Pollutant Load

Simple Method Calculation:

$L = P \times P_j \times R_v \times C \times A \times 2.72/12$

Where:

L = total post-development pollutant load (pounds/ year)
P = average annual rainfall depth (inches) = 43 inches for Virginia
P_j *= fraction of rainfall events that produce runoff = 0.9*
R_v *= runoff coefficient = [0.05 + (0.009 x I)]*
where: I = percent impervious cover, expressed as whole number, modified by LID credits
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L)
A = area of the development site (acres)
2.72 and 12 are unit conversion factors

C values are as follows:

	Total Phosphorus	***Total Nitrogen***
Low Impervious Sites (< 40%)	*0.28 mg/L*	*2.67 mg/L*
High Impervious Sites (> 40%)	*0.23 mg/L*	*1.12 mg/L*

Low Impervious Loads (pounds/year)

$L_{TP} = R_v \times 2.46 \times A$

$L_{TN} = R_v \times 23.42 \times A$

High Impervious Loads (pounds/year)

$L_{TP} = R_v \times 2.02 \times A$

$L_{TN} = R_v \times 9.82 \times A$

PCM STEP 2: Calculate Pollutant Removal Requirement

$RR_{TP} = L_{TP} – (S_{TP} \times A)$

$RR_{TN} = L_{TN} – (S_{TN} \times A)$

Where:

RR_{TP} = *Total Phosphorus removal requirement (pounds/year)*
RR_{TN} = *Total Nitrogen removal requirement (pounds/year)*
L_{TP} = *Total Phosphorus post-development pollutant load (pounds/year) (Step 1)*
L_{TN} = *Total Nitrogen post-development pollutant load (pounds/year) (Step 1)*
S_{TP} = *Total Phosphorus performance standard (pounds/acre/year) (see below)*
S_{TN} = *Total Nitrogen performance standard (pounds/acre/year) (see below)*

S values are as follows:

	S_{TP}	S_{TN}
Low Impervious Sites (< 40%)	*0.28 lbs/acre/year*	*3.00 lbs/acre/year*
High Impervious Sites (> 40%)	*0.45 Lbs/acre/year*	*2.68 Lbs/acre/year*

PCM STEP 3: Calculate BMP Efficiency Requirement

$EFF_{TP} = (RR_{TP} / L_{TP}) \times 100$

$EFF_{TN} = (RR_{TN} / L_{TN}) \times 100$

Where:

EFF_{TP} = *Total Phosphorus required pollutant removal efficiency*
EFF_{TN} = *Total Nitrogen required pollutant removal efficiency*
RR_{TP} = *Total Phosphorus removal requirement (pounds/year) (Step 2)*
RR_{TN} = *Total Nitrogen removal requirement (pounds/year) (Step 2)*
L_{TP} = *Total Phosphorus post-development pollutant load (pounds/year) (Step 1)*
L_{TN} = *Total Nitrogen post-development pollutant load (pounds/year) (Step 1)*

PCM STEP 4: Select Applicable BMPs

FIRST – review application of LID Credits to see if credits can be applied to develop an "Adjusted BMP Removal Rate." This can reduce the need for structural BMPs and/or their number, size, and cost.

$BMP_{RETP} = EFF_{TP}$

$BMP_{RETN} = EFF_{TN}$

Where:

BMP_{RETP} = *BMP Efficiency for Total Phosphorus (see below)*
EFF_{TP} = *Total Phosphorus required pollutant removal efficiency(Step 3)*
BMP_{RETN} = *BMP Efficiency for Total Nitrogen (see below)*
EFF_{TN} = *Total Nitrogen required pollutant removal efficiency(Step 3)*

BMP Type	TP Removal Efficiency	TN Removal Efficiency
Wet Pond 1	50%	30%
Wet Pond 2	75%	40%
Bioretention 1	45%	45%
Bioretention 2	55%	55%
Infiltration 1	65%	40%
Infiltration 2	95%	65%
Constructed Wetland 1	45%	25%
Constructed Wetland 2	75%	55%
WQ Swale 1	25%	45%
WQ Swale 2	45%	55%
Filtering Practice	65%	50%

Section 4

Sample BMP Design Checklists

(Bioretention)

Bioretention #1

Removal Rates:
Total Phosphorus = 45%
Total Nitrogen = 45%

Design Checklist

? Design Capacity Meets or Exceeds 1.0" of storage over the drainage area, according to the following calculation:

Total Storage = Free Storage + (Soil Volume x 0.20)

Where: Free Storage = storage between soil surface and overflow device
Soil Volume = total volume of soil media, not counting underdrain gravel

? Filter surface area (not counting side slopes) exceeds 3% of contributing drainage area

? Soil media is at least 24" deep and meets the following specifications:

- 85% sand
- 10% fines (clay and silt)
- 5% organic material (newspaper or composted leaf mulch, peat, etc.)
- Phosphorus index between 10 and 30

The soil media should be provided by a qualified vendor, OR mixed and tested prior to placement.

? Designed for infiltration (if underlying soils are suitable and tested) OR for filtration with underdrain

- For infiltration designs, underlying soil must be tested and have an infiltration rate of 0.5 to 2 inches per hour.

? At least 1 form of pre-treatment provided. Pre-treatment options include:

- 2-cell design
- Pre-treatment cell (forebay)
- Grass swale or channel (at least 10' flow path)
- Rock or gravel apron or strip (1' wide)
- Sod perimeter of filter bed (4' wide)
- Storage manhole or hydrodynamic structure

? Planting plan includes herbaceous layer (can be grass), shrubs, and trees to achieve 90% coverage of filter bed surface area within 3 years. Surface should be covered by mulch, appropriate matting (coconut fiber, etc.), or sod.

? Off-line design with by-pass of high flows around filter bed

? Other design specifications:

- Drainage area does not exceed 2 acres
- No filter fabric between soil media and underdrain and/or underlying soil – use 2" of choker stone (#8 or #78) and 3" of pure sand in lieu of filter fabric
- Does not accept base flow or chlorinated flow
- Does not treat runoff from pollution hotspot
- Is not within flood plain
- Has at least 1' of separation from bottom of cell to seasonal high water table

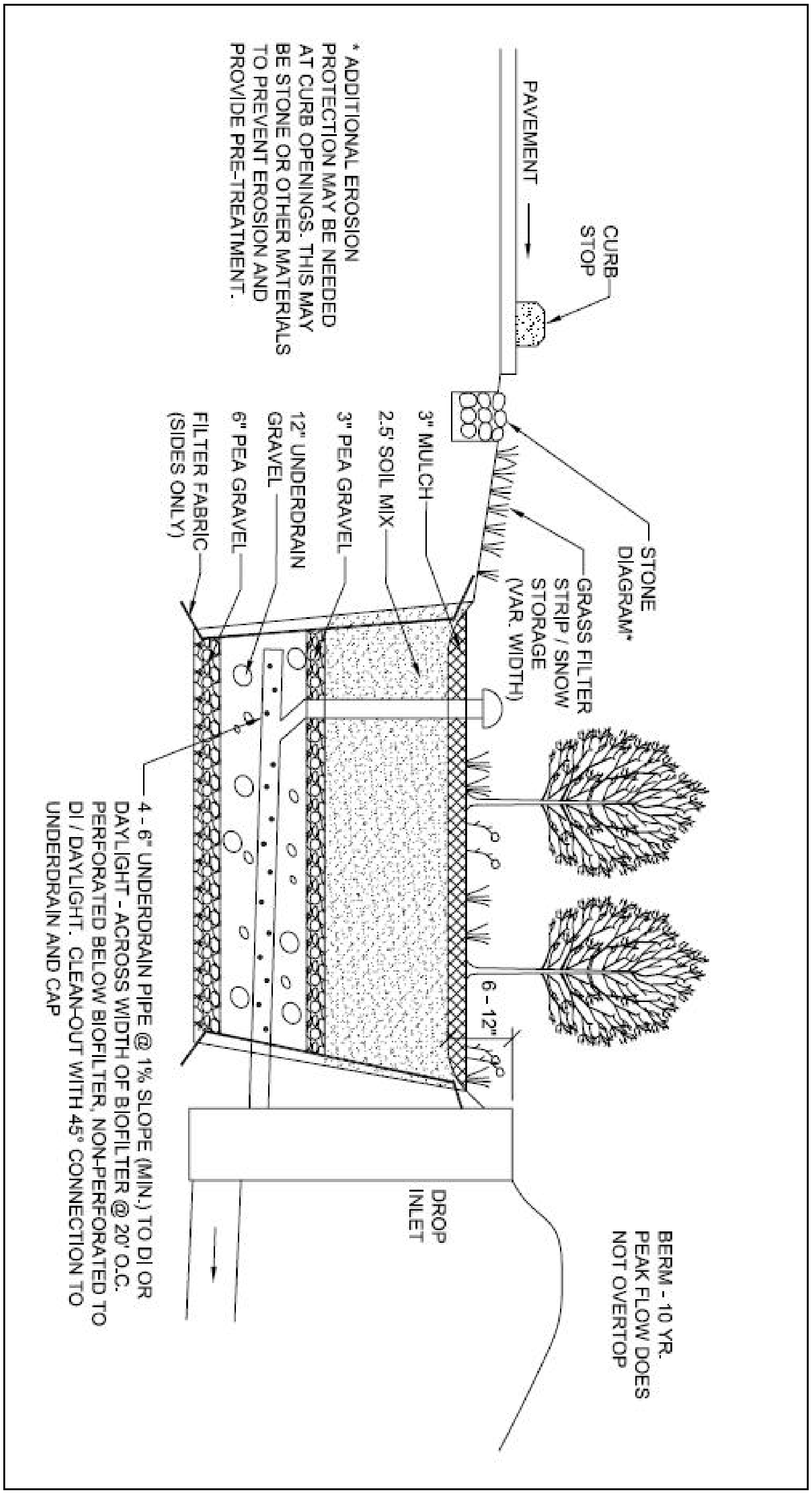


Figure 4.1: Bioretention #1 (DRAFT – to be completed with Handbook updates)

Bioretention #2

Removal Rates:
Total Phosphorus = 55%
Total Nitrogen = 55%

Design Checklist

? Design Capacity Meets or Exceeds 1.2” of storage over the drainage area, according to the following calculation:

Total Storage = Free Storage + (Soil Volume x 0.20)

Where: Free Storage = storage between soil surface and overflow device
Soil Volume = total volume of soil media, not counting underdrain gravel

? Filter surface area (not counting side slopes) exceeds 5% of contributing drainage area

? Soil media is at least 36” deep and meets the following specifications:

- 85% sand
- 10% fines (clay and silt)
- 5% organic material (newspaper or composted leaf mulch, peat, etc.)
- Phosphorus index between 10 and 30

The soil media should be provided by a qualified vendor, OR mixed and tested prior to placement.

? Designed for infiltration OR gravel sump provided below underdrain.

- For infiltration designs, underlying soil must be tested and have an infiltration rate of 0.5 to 2 inches per hour.
- For underdrain designs, at least 1’ of storage should be provided below invert of underdrain pipe(s).

? At least 2 forms of pre-treatment provided. Pre-treatment options include:

- 2-cell design
- Pre-treatment cell (forebay)
- Grass swale or channel (at least 10’ flow path)
- Rock or gravel apron or strip (1’ wide)
- Sod perimeter of filter bed (4’ wide)
- Storage manhole or hydrodynamic structure

? Planting plan includes herbaceous layer, shrubs, and trees to achieve 90% coverage of filter bed surface area within 3 years. Surface should be covered by mulch or appropriate matting (coconut fiber, etc.).

? Off-line design with by-pass of high flows around filter bed

? Other design specifications:

- Drainage area does not exceed 1 acre
- No filter fabric between soil media and underdrain and/or underlying soil – use 2" of choker stone (#8 or #78) and 3" of pure sand in lieu of filter fabric
- Does not accept base flow or chlorinated flow
- Does not treat runoff from pollution hotspot
- Is not within flood plain
- Has at least 1' of separation from bottom of cell to seasonal high water table

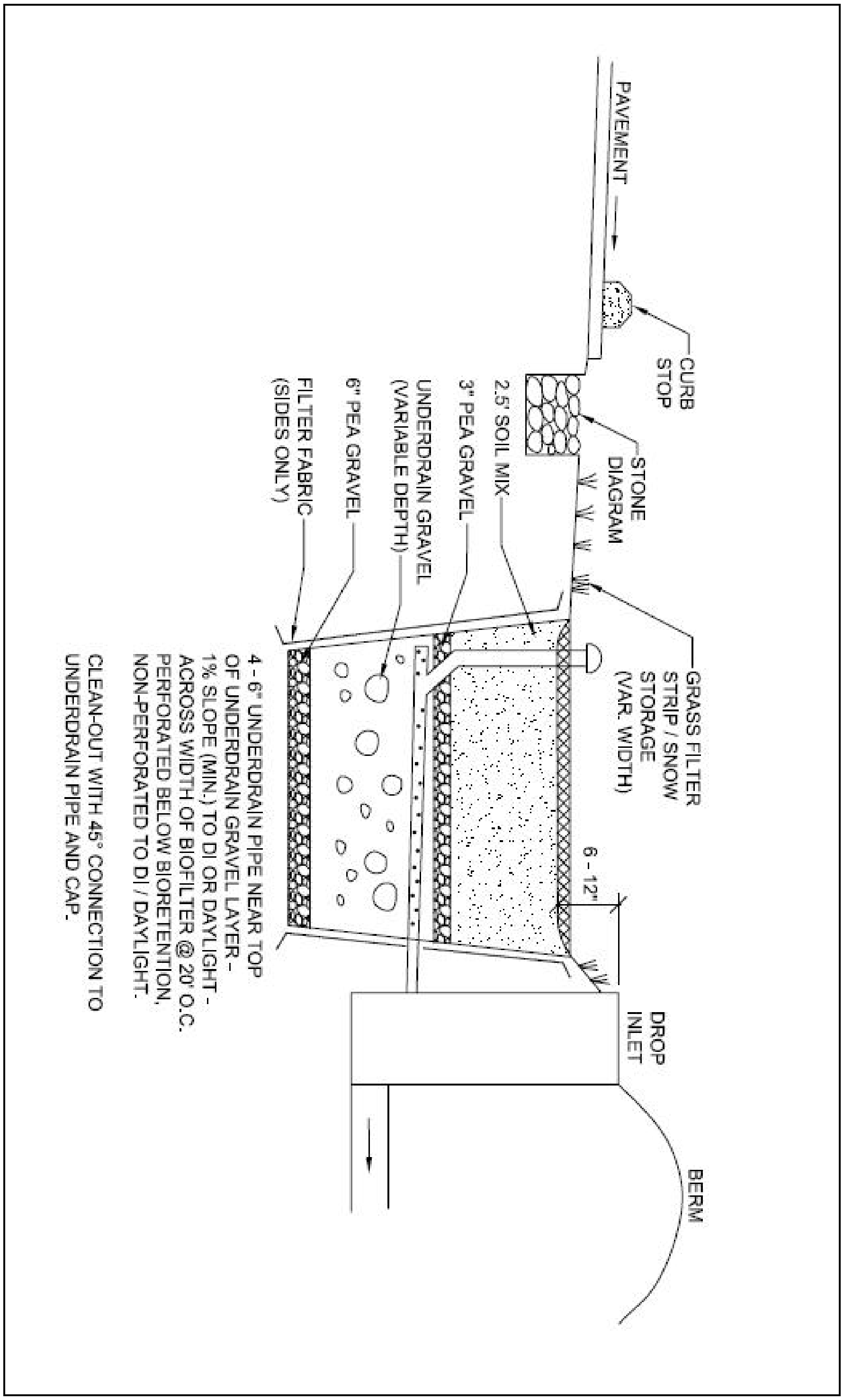


Figure 4.2: Bioretention #2 (DRAFT – to be completed with Handbook updates)

References for Bioretention Design Information

Davis, A.P., M. Shokouhian, H. Sharma and C. Minami. 2001. Laboratory Study of Biological Retention for Urban Stormwater Management. *Water Environment Research.* 73(5): 5-14.

Davis, A.P., M. Shokouhian, H. Sharma, C. Minami and D. Winogradoff. 2003. Water Quality Improvement Through Bioretention: Lead, Copper, and Zinc Removal. *Water Environment Research.* 75(1): 73-82.

Davis, A.P., M. Shokouhian, H. Sharma and C. Minami. 2006. Water Quality Improvement through Bioretention Media: Nitrogen and Phosphorus Removal. *Water Environment Research.* 78(3): 284-293.

Dietz, M.E. and J.C. Clausen. 2005. A Field Evaluation of Rain Garden Flow and Pollutant Treatment. *Water, Air & Soil Pollution*. 167: 123-138.

*Dietz, M.E. and J.C. Clausen. 2006. Saturation to Improve Pollutant Retention in a Rain Garden. *Environmental Science &Technology.* 40(4): 1335-1340.

*Ermilio, J.R. 2005. Characterization Study of a Bio-Infiltration Stormwater BMP. M.S. Thesis. Villanova University. Department of Civil and Environmental Engineering. Philadelphia, PA.

*Glass, C. and S. Bissouma. No Date. Evaluation of a Parking Lot Bioretention Cell for Removal of Stormwater Pollutants. Howard University. Department of Civil Engineering. Washington, DC.

Hunt, W.F. III. 2003. Bioretention Use and Research in North Carolina and other Mid-Atlantic States. *North Carolina State University Water Quality Group Newsletter.* NWQEP Notes. 109. North Carolina State University. Raleigh, NC.

*Hunt, W.F. III, A.R. Jarrett, J.T. Smith, and L.J. Sharkey. 2006. Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina. *ASCE Journal of Irrigation and Drainage Engineering.* 132(6): 600-608.

Hunt, W.F. III and W.G. Lord. 2006. Bioretention Performance, Design, Construction, and Maintenance. *North Carolina Cooperative Extension Service Bulletin.* Urban Waterways Series. AG-588-5. North Carolina State University. Raleigh, NC.

Hsieh, C.-H. and A.P. Davis. 2005. Multiple-Event Study of Bioretention for Treatment of Urban Storm Water Runoff. *Water Science and Technology.* 51(3-4): 177-181.

Hsieh, C.-H. and A.P. Davis. 2005. Evaluation and Optimization of Bioretention Media for Treatment of Urban Storm Water Runoff. *ASCE Journal of Environmental Engineering.* 131(11): 1521-1531.

Kim, H., E.A. Seagren and A.P. Davis. 2003. Engineered Bioretention for Removal of Nitrate From Stormwater Runoff. *Water Environment Research*. 75(4): 355-367.

McCuen, R.H. and O. Okunola. Extension of TR-55 for Microwatersheds. 2002. *Journal of Hydrologic Engineering*. 7(4): 319-325.

Perez-Pedini, C., J.F. Limbrunner and R.M. Vogel. 2005. Optimal Location of Infiltration-Based Best Management Practices for Stormwater Management. *ASCE Journal of Water Resources Planning and Management*. 131(6): 441-448.

*Smith, R.A. and W.F. Hunt. No Date. Pollutant Removal in Bioretention Cells with Grass Cover. North Carolina State University. Raleigh, NC.

University of New Hampshire Stormwater Center. 2005. 2005 Data Report. University of New Hampshire Stormwater Center. Durham, NH.

Van Seters, T., D. Smith and G. MacMillan. 2006. Performance Evaluation of Permeable Pavement and a Bioretention Swale. 8th International Conference on Concrete Block Paving. San Francisco, CA. November, 2006.

*Yu, S.L. and M.D. Stopinski. 2001. Testing of Ultra-Urban Stormwater Best Management Practices. VTRC 01-R7. Virginia Transportation Research Council. Charlottesville, VA.